INDIVIDUAL DIFFERENCES IN WORKING MEMORY CAPACITY PREDICT PERSONALITY

by

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ABSTRACT

Understanding the relationships between personality and cognitive ability has implications for how we characterize and even diagnose cognitive impairment. While many studies have investigated relationships between personality and executive functions, few have directly studied personality in relation to working memory (WM), specifically. In addition, results from such studies have been inconclusive. The present study examined the relationships between WM and the Five Factor Model of personality in a large sample (*n*=354) of young adults. Results revealed that increased Neuroticism is associated with poorer WM performance, while higher Openness to Experience is associated with improved WM performance. Implications for dual mechanism theories of attentional control are discussed.

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INTRODUCTION

Relationships between personality and cognitive function have become a topic of increasing interest in cognitive psychology. Understanding the relationships between personality and cognitive ability has implications for how we characterize and even diagnose cognitive impairment. Researchers have found relationships between personality and cognitive dysfunction in disorders ranging from ADHD (e.g., Parker, Majeski, & Collin, 2004) to Alzheimer's dementia (e.g., Duchek, Balota, Storandt, & Larsen, 2007). For example, Duchek and colleagues (2007) found that measures of the personality characteristics neuroticism and conscientiousness were significant predictors of early Alzheimer's dementia beyond measures of memory and general cognitive ability. Myriad studies have inquired into the relationships between personality and executive functions, but only a handful of studies have directly investigated personality as it relates to working memory (Chavanon, Wacker, Leue, & Stemmler, 2007; Cools, Sheridan, Jacobs, & D'Esposito, 2007; Derakshan & Eysenck, 1998; DeYoung, Shamosh, Green, Braver, & Gray, 2009; Gray & Braver, 2002; Gray et al., 2005; Lieberman, 2000). The purpose of the current study was to examine associations between personality and working memory in a large sample of healthy young adults.

Working Memory and Attentional Control

Current theories of working memory (WM) conceptualize WM ability as an interaction between memory and executive attention systems. Executive attention is engaged during complex cognitive tasks and appears to support goal maintenance in the presence of conflict (e.g., between stimuli or task goals) and distraction. WM span tasks, such as the operation span (OSpan) task, have been shown to be strong measures of executive attention (Conway et al., 2005; Kane, Conway, Miura, & Colflesh, 2007). In an operation span task, participants are typically asked to learn a list of words while performing some unrelated task (e.g., an arithmetic problem) between the presentations of each word. A number of studies have demonstrated that performance on complex WM span tasks correlates strongly with measures of fluid intelligence, while simpler tests of short term memory do not (Engle, Kane, & Tuholski, 1999). In addition, WM span tasks have been shown to reliably predict performance on a variety of executive function tasks including Stroop, dichotic listening and antisaccade tasks (see Conway & Kane, 2001, for a review). Kane and Engle (2002) interpret these findings as support for their argument that WM is strongly influenced by executive attention.

Building on Kane and Engle's work, Braver, Gray, and Burgess (2007) developed the dual mechanisms of control (DMC) theory, which proposes two forms of attentional control. Reactive control refers to automated, bottom-up attentional control processes in which the engagement of control is activated involuntarily on an as-needed basis by some external cue. Proactive control may be another term for executive attention (Kane, Conway, Hambrick, et al., 2007) and refers to top-down attentional control processes that are important for tasks such as goal maintenance in which a goal is internally determined prior to the onset of a task and is actively maintained throughout the task. Braver and colleagues argue that the DMC theory provides a framework for interpreting relationships between WM and personality traits. The theory posits that individual differences in the relative engagement of reactive and proactive control mechanisms may explain why personality factors are related to cognitive task performance.

Braver and colleagues suggest that proactive control is related to motivation, goal-directed behaviors, and sensitivity to reward, which they argue are characteristics of the personality trait extraversion. Reactive control is thought to be related to threat detection, sensitivity to punishment, and withdrawal behaviors, which they liken to the personality trait neuroticism. Thus, the DMC theory predicts that on tasks requiring proactive control (i.e., WM capacity tasks, such as operation span) higher extraversion should be associated with better performance because extraversion is related to strong proactive attentional control capacity. On the other hand, the DMC theory predicts that individuals high in neuroticism should exhibit a decrement in performance on tasks with greater demand for proactive control mechanisms because they tend to rely more on reactive control strategies and may not have particularly strong proactive control capacity. Alzheimer's patients may represent an extreme example of an imbalance between reactive and proactive control. As proactive control mechanisms break down in dementia, these individuals may rely more on reactive control processes and hence develop increased neuroticism as reported by Duchek et al. (2007). Consistent with this argument, AD patients show deficits on many of the tasks thought to require intact goal maintenance or proactive control, such as Stroop color naming (Spieler, Balota, & Faust, 1996) or the Simon task (Castel, Balota, Hutchison, Logan, & Yap, 2007).

Personality and Working Memory

Studies of personality and WM have primarily focused on trait measures relating to neuroticism and extraversion. Neuroticism is characterized by a propensity to experience anxiety and related negative affects, such as depression and anger (Costa & McCrae, 1992). Neuroticism has also been shown to correlate with behavioral inhibition, or sensitivity to punishment and threat (Carver, Sutton, & Scheier, 2000). Ample evidence exists for a negative relationship between WM and neuroticism. WM has been shown to be associated with trait anxiety (Derakshan & Eysenck, 1998; Owens, Stevenson, Norgate, & Hadwin, 2008) and poor emotion regulation (Schmeichel, Volokhov, & Demaree, 2008). Shackman and colleagues (2006) found that higher anxiety and self-reported behavioral inhibition was associated with poorer performance on a verbal/spatial *n*-back task. In an *n*-back task, a stream of letters is presented one at a time to participants who are asked to decide if the letter presented is the same as that presented *n* letters previously.

Results from studies of WM and extraversion have been less consistent. The term extraversion has been used to refer to sociability, a propensity to experience positive emotion, and excitement seeking (Costa & McCrae, 1992). Extraversion has also been shown to correlate with behavioral activation, the tendency to actively seek out reward or pleasure (Carver et al., 2000). Gray and Braver (2002) found that behavioral activation was associated with better performance on an *n*-back task. However, a related study by Gray, Burgess, Schaefer, Yarkoni, Larsen, and Braver (2005) was unable to replicate this finding. Lieberman and Rosenthal (2001) demonstrated that extraversion, as measured by the Eysenck Personality Questionnaire (Eysenck & Eysenck, 1968), was associated with faster reaction times in an *n*-back task, but was not associated with WM accuracy.

One possible explanation for the lack of consistent findings regarding the relationship between extraversion and WM could be inadequate operationalization of attentional control and/or the personality trait with which it is hypothesized to correlate. For example, the *n*-back task employed in previous studies requires short term memory, but may not put sufficient demand on attentional control mechanisms to produce an observable effect. Kane and colleagues (2007) have proposed that operation span tasks place high demand on attentional control resources and thus may be more sensitive WM measures than *n*-back tasks, which they argue are relatively weak measures of WM capacity and attentional control.

Regarding measurement of personality, Gray and colleagues (2002; 2005) assess personality using Carver and White's (1994) behavioral inhibition and activation scales (BIS/BAS). These measures are less commonly used in personality assessment and thus not as well studied compared to measures like the NEO Personality Inventory (Costa & McCrae, 1992), which is based on the Five Factor Model of personality. The Five Factor Model includes five domains of personality: Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness (see Table 1 for descriptions). The BIS/BAS measures have been shown to correlate with measures of neuroticism and extraversion, respectively (Carver et al., 2000; Gray et al., 2005), but have only been hypothesized to correlate with the FFM traits of Neuroticism and Extraversion. Furthermore, the BIS/BAS scales and measures of the FFM traits of Neuroticism and Extraversion do not assess equivalent constructs. The BIS was designed to measure inhibition of goal-seeking behavior, which is thought to underlie trait anxiety and negative affect. The BAS was designed to measure motivation to achieve goals, and is thought to underlie positive affect (Carver & White, 1994).

One may also question whether Extraversion is the best proxy for a propensity for high proactive control. If proactive control is most active under conditions of distraction or conflict, a more appropriate personality associate could be Openness to Experience. Individuals high in Openness are intellectually curious, drawn to novelty, and have high cognitive flexibility (Costa & McCrae, 1992). These characteristics may be the result of strong proactive control mechanisms that enable these individuals to cognitively adapt to novelty. Two studies by DeYoung and colleagues (DeYoung, Peterson, & Higgins, 2005; DeYoung, Shamosh, Green, Braver, & Gray, 2009) offer support for a relationship between Openness and proactive control. DeYoung et al. (2005) showed that Openness was positively correlated with several measures associated with dorsolateral prefrontal cortex, which is thought to be a key region that supports proactive control. DeYoung et al. (2009) found that high Openness was associated with better performance on a 3-back WM task. However, their data did not support a relationship between WM task performance and Neuroticism or Extraversion.

Furthermore, due to the large variability in personality traits and cognitive ability across individuals, relationships between cognition and personality tend to be small. Effects of this magnitude are difficult to observe in small samples. The studies conducted by Gray and colleagues (2002; 2005) and Lieberman and Rosenthal (2001) had samples sizes of approximately 60 or less; thus, they may not have had sufficient power to detect small effects.

The Current Study

The present study investigated the relationships between WM and the Five Factor Model of personality in a large sample of young adults using an attentionally demanding operation span task. The aims of the study were twofold. First, we aimed to investigate the relationship between WM and Neuroticism using a more rigorous test of WM capacity. The DMC theory of WM predicts that individuals high in neuroticism should show poorer performance on tasks that place high demands on proactive control mechanisms due to a relative weakness in proactive compared to reactive control. Previous research regarding the relationship between neuroticism and WM lends ample support for this claim. However, the relationship has traditionally been tested with less rigorous WM measures.

Second, we aimed to determine which FFM personality factor, Extraversion or Openness, demonstrates a stronger relationship with proactive control as measured by a WM span task. As stated above, previous studies of the relationships between WM and extraversion have yielded mixed results. If extraversion is positively correlated with WM capacity, this association should be detected by the present study, which has ample power and employs more traditional measures of WM capacity and personality constructs. However, as discussed earlier, we hypothesized that the mixed findings regarding WM and extraversion are the result of inadequate operationalization of the personality construct. That is, a more appropriate correlate of proactive control could be Openness to Experience, which is associated with greater cognitive flexibility and attraction to novelty. Thus, we predicted that Openness would be more likely to show a significant relationship with WM capacity than would Extraversion.

Table 1

Domains of the Five Factor Model of Personality

Factor	Description
Neuroticism	Emotional instability, tendency toward negative emotion, susceptibility to stress, poor impulse control
Extraversion	Sociability, excitement/stimulus seeking, tendency toward positive emotionality
Openness to Experience	Intellectual curiosity, attentiveness feelings, sensitivity to aesthetics
Agreeableness	Interpersonal interest, sympathy, altruism
Conscientiousness	Self-control, organization, planning, dependability

METHOD

Participants and Procedure

A total of 403 participants were recruited from undergraduate psychology courses at the University of Utah. All participants gave informed consent and received course credit for their participation. Volunteers provided demographic information including age, gender, years of education, handedness, race and ethnicity, and English fluency. Exclusion criteria included nonfluency in English, and age less than 18 or greater than 30 years. On the basis of these exclusion criteria, 32 participants were excluded from the study. The remaining 371 participants completed a computerized version of the NEO Five Factor Inventory (NEO-FFI) and an automated operation span (AOSpan) task. Both tasks were administered using E-Prime version 1.1. Participants were tested on individual computers in groups of up to 5 people.

Measures

NEO Five Factor Inventory (Costa & McCrae, 1992). The NEO-FFI is a 60-item short form of the NEO Personality Inventory (NEO-PI-R; Costa & McCrae, 1992), which is a self-report questionnaire that assesses the FFM personality factors of Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness. Participants rate each item on a five-point Likert scale ranging from 0 (strongly disagree) to 4 (strongly agree) (note: some items are reverse-scored). Raw scores for each of the five factors are calculated by summing the scores for each item for that factor and have a range of 0 to 48. Correlations of NEO-FFI with NEO-PI-R factors range from .75 for Conscientiousness to .89 for Neuroticism. Internal consistency for the NEO-FFI factors ranges from .68 for Agreeableness to .86 for Neuroticism (Costa & McCrae, 1992).

AOSpan (Unsworth, Heitz, Schrock, & Engle, 2005). The automated operation span (AOSpan) is a computer-administered operation span task. A detailed explanation of the task can be found in Unsworth et al. (2005). In the AOSpan, participants are asked to solve simple math problems. A time limit is imposed for solving. The time limit for each participant is calculated using solve times on a set of 15 practice problems and is equal to their average solving time plus 2.5 standard deviations. Each math operation is followed by the brief presentation of a letter. Participants are presented with 3 to 7 operation-letter pairs per set. At the end of each set, they are asked to recognize the letters that were presented, in order, selecting them from a field of 12 presented and non-presented letters. Participants are instructed to maintain a minimum of 85% accuracy on the math portion of this task.

The AOSpan yields several measures including absolute WM span, partial WM span, math speed errors, and math accuracy errors. The absolute span score is calculated as the sum of scores for all perfectly recalled sets. A more liberal partial span score indicates the total number of letters correctly recalled in the correct serial position. Speed errors refer to errors in which the participant is unable to respond to the mathematical operation within the time allowed. Accuracy errors occur when the participant responds incorrectly to a mathematical operation. The AOSpan task also provides solve times in milliseconds for each mathematical operation.

RESULTS

Of the 371 participants noted above, 8 were removed from analyses for incomplete data. Participants whose math accuracy fell below 80% (*n*=9) were also removed from the sample, to ensure compliance with the task instructions during the AOSpan task. The final sample of 354 participants ranged in age from 18-35 (*M*=21.42, *s.d.*=3.18) and was 53.4% female. Descriptive statistics for the AOSpan and NEO-FFI measures are displayed in Table 2. Descriptive statistics for the AOSpan were commensurate with those reported in Unsworth et al. (2005). Variables used in the analysis were relatively normally distributed and no outliers were detected.

Zero-order correlations among NEO-FFI factors and absolute AOSpan are displayed in Table 3. WM span had small, but significant correlations with Neuroticism (r=-.141, p=.008, Cohen's d=.285) and Openness (r=.119, p=.025, Cohen's d=.240), but not with Extraversion (r=.059, p=.271). See Figure 1 for scatterplots. To further characterize these relationships, one-way analyses of variance (ANOVA) were performed for Neuroticism and Openness grouping participants into low, middle, and high AOSpan performance. The groups did not differ in age or gender. Means for the ANOVAs are presented in Figure 2. Because we were most interested in the distinction between high and low WM span performers, we computed a priori comparisons for these groups. A typical approach in the literature examining individual differences in WM capacity involves comparing extreme groups (Conway et al., 2005). The ANOVA for Neuroticism was significant (*F*[2,351]=5.081, *p*=.007). The low-high WM span comparison was also significant (*t*(2,351)=3.07, *p*=.002, Cohen's *d*=0.395), indicating that individuals with low WM capacity tend to rate themselves higher on Neuroticism than those with high WM capacity. The ANOVA for Openness was not significant (*F*[2,351]=1.273, *p*=.281) nor was the low-high WM span comparison (*t*(2,351)=-1.169, *p*=.243). Though the ANOVA was not significant, the correlation between Openness and WM span suggests that high WM capacity is at least weakly associated with higher self-reported Openness.

Table 2

Descriptive Statistics for Study Variables

	Mean	Std Dev.	Min	Max	Skewness	Kurtosis
Absolute AOSpan	41.35	18.01	0	75	-.28	-.65
Total Errors	5.51	3.08	0	14	.51	-.18
Neuroticism	20.21	8.09	0	43	.12	-.07
Extraversion	31.52	6.33	9	46	-.34	.03
Openness	29.40	6.22	14	44	-.09	-.48
Agreeableness	32.01	5.91	6	44	-.74	1.08
Conscientiousness	33.04	6.57	11	48	-.46	.23

Table 3

Pairwise Pearson Correlations for NEO-FFI

Factors and Absolute OSpan

	Total Errors[†]	N	E	O	A	C
AOSpan	-.378**	-.141**	.059	.119*	.056	-.040
Total Errors	—	.064	.030	-.091	-.061	-.048
Neuroticism	—	—	-.406**	.049	-.159**	-.334**
Extraversion	—	—	—	-.046	.194**	.261**
Openness	—	—	—	—	.041	-.092
Agreeableness	—	—	—	—	—	.138**

**p* <.05, ***p*<.01

[†]Note: AOspan=Absolute automated operation span score, Total Errors=Total number of errors on math problems, N=Neuroticism, E=Extraversion, O=Openness to Experience, A=Agreeableness, C=Conscientiousness

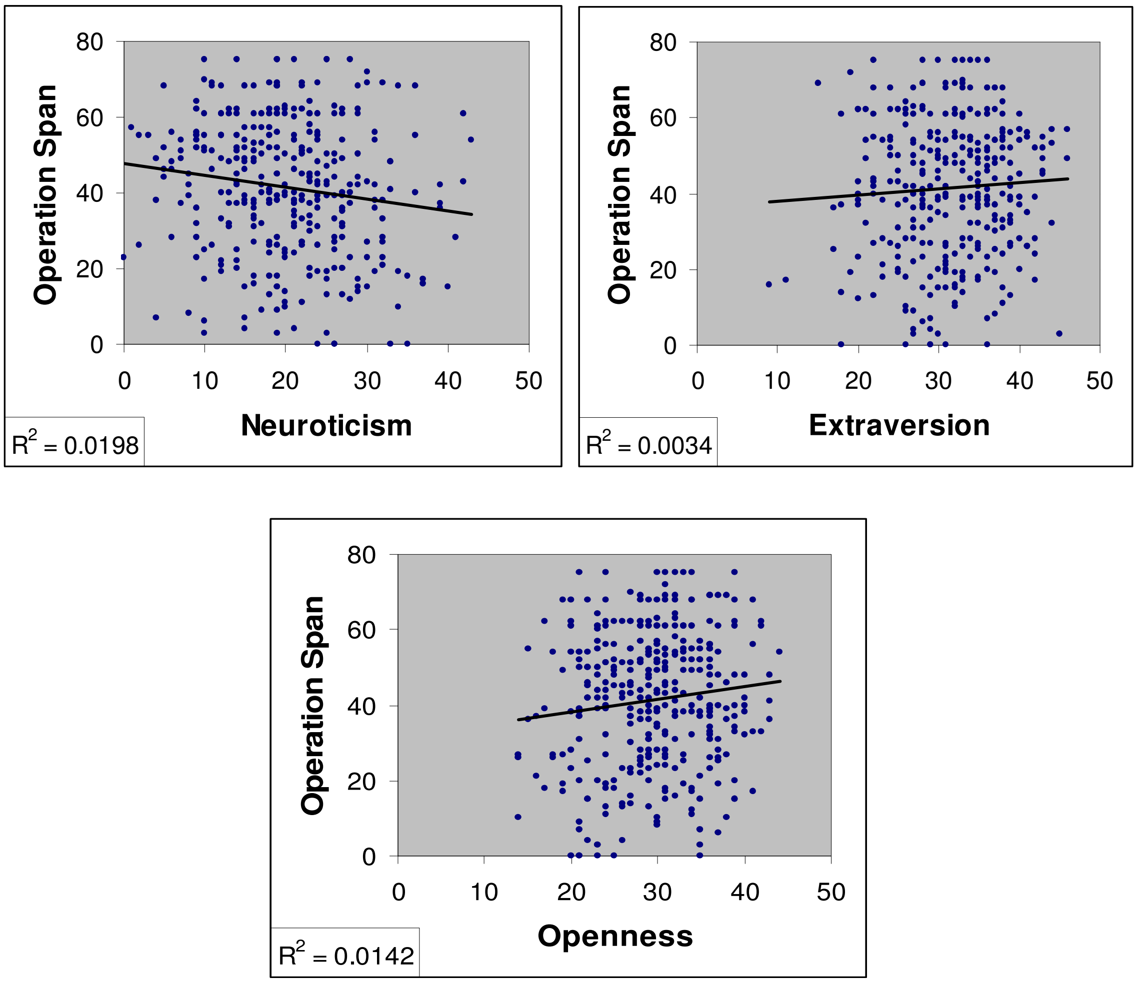

Figure 1

Scatterplots for Correlations between AOSpan and

Neuroticism, Extraversion, and Openness

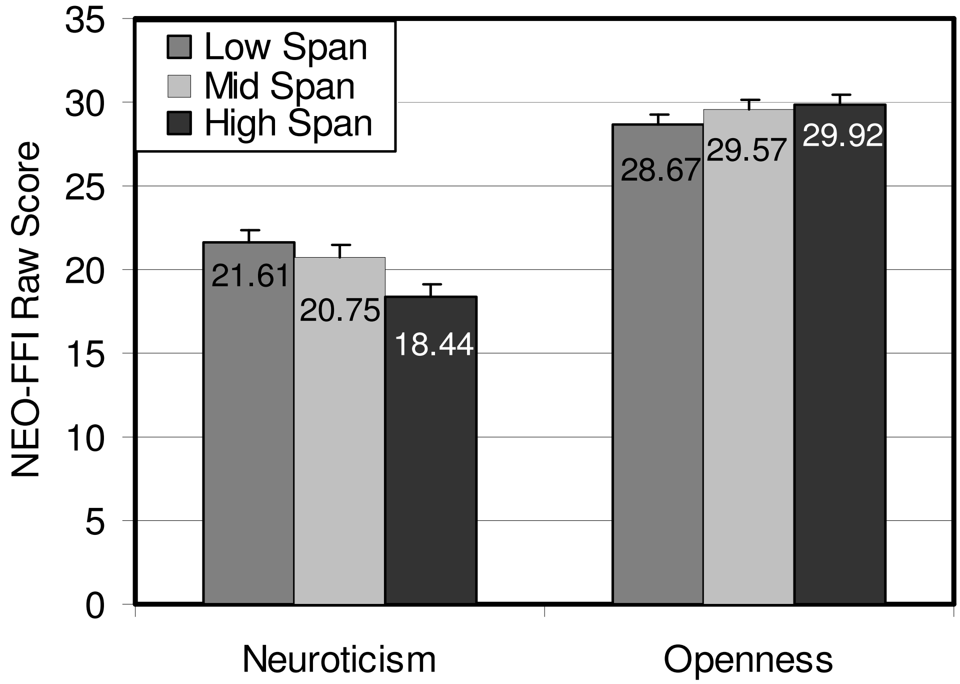

Figure 2

Means and standard error for Neuroticism and Openness by AOSpan Group

DISCUSSION

The DMC theory of WM and cognitive control makes two main predictions regarding the relationship between WM capacity and personality: neuroticism should be negatively correlated with WM capacity, while extraversion should be positively correlated with WM capacity. While support for these hypotheses exists, the results from studies of WM capacity and personality have been inconclusive. The present study was conducted to address two main goals. First, we sought to provide a more rigorous test of the DMC theory's predicted relationship between neuroticism and WM capacity using a more complex measure of WM capacity. OSpan tasks provide a more rigorous test of WM capacity than do *n*-back tasks because OSpan tasks place high demands on goal-maintenance and attentional control. These increased demands should result in a broader range of scores for WM capacity and increase the power of the study. The literature indicates that characteristics of high neuroticism are associated with decrements in performance on WM and other executive tasks. Consistent with earlier studies, we found that higher Neuroticism is associated with poorer performance on a complex task of WM capacity. However, the only other study to date that has examined WM capacity and the FFM trait of Neuroticism (DeYoung et al., 2009) found no relationship between the two. In that study WM capacity was assessed using the average of scores on 4 WM span tasks, including the OSpan. FFM personality traits were correlated with this combined WM capacity score, WM accuracy on an *n*-back task, and functional magnetic resonance imaging (fMRI) activation during *n*-back performance. Aside from a few significant correlations with Openness to Experience, no relationships were observed between personality traits and the various measures of WM.

Second, following up on the results found by DeYoung and colleagues (2009), we aimed to demonstrate that Openness to Experience may be a better noncognitive correlate of WM capacity than Extraversion within the framework suggested by the DMC theory. The proposed positive relationship between WM and extraversion has not been consistently observed (Gray, Braver, & Raichle, 2002; Gray et al., 2005; Lieberman & Rosenthal, 2001) nor was it observed in the study by DeYoung and colleagues (2009). Our data did not support a relationship between Extraversion and WM capacity. However, we observed a small relationship between WM capacity and the FFM trait Openness to Experience. This finding is consistent with that of DeYoung and colleagues (2009). Thus it appears that Openness to Experience may be a better personality correlate of WM capacity than is Extraversion.

Theoretical and Clinical Implications

Examining the relationships between cognitive measures and more realistic measures of functioning, such as personality, allows us to examine how individual differences in cognition play out in everyday life (Watson, Lambert, Miller, & Strayer, in press). McVay and Kane (2009) are pursuing this line of research by investigating how WM capacity is associated with a person's ability to inhibit task-unrelated thoughts. For example, in a recent study they found that lower working memory capacity was associated with an increase in the incidence of task-unrelated thoughts while performing a test of sustained attention (McVay & Kane, 2009). With regard to personality, the results of the present study suggest that individuals with lower WM or attentional control capacity may demonstrate more anxious behaviors in day-to-day life while those with higher WM or attentional control capacity may exhibit an exploratory nature and attraction to novel experiences.

Studies of personality-cognition relationships also have implications for understanding clinical disorders in which individuals exhibit extreme personality characteristics or levels of cognitive ability. Extremely high Neuroticism or low Openness may suggest a weakness in WM capacity or other attentional control abilities. For example, Duchek and colleagues (2007) have shown that the FFM has predictive utility beyond tests of memory and general cognitive ability in identifying individuals with very early stage Alzheimer's dementia. Perhaps the predictive utility of neuroticism is due to declining attentional control in these patients as they begin to suffer neurodegeneration in prefrontal cortex.

Limitations and Future Directions

The present study provided the first large-scale (N>300) assessment of relationships between working memory capacity and personality traits. However, as it is the first of this kind, it has several limitations that should be addressed in future studies. First, future work should build on the present study by including more than one measure of attentional control. In order to more fully characterize the relationship between the FFM and attentional control, several cognitive measures should be employed to determine whether the observed effects are generalizable to the broader concept of attentional control. For example, in order to make more conclusive statements about the relationship between the FFM traits and dual mechanism theories of attentional control, such as that proposed by Braver and colleagues (2007), inclusion of measures assessing both reactive and proactive forms of control would be useful. This approach would be consistent with more traditional experimental approaches that attempt to use process dissociation techniques. The results of the present study, particularly the negative relationship between working memory capacity and neuroticism, suggest that dissociation between proactive and reactive control can be made using personality measures.

Second, each of the FFM traits assesses subordinate traits, or facets of personality. For example, Neuroticism includes six facets that assess anxiety, anger, depression, self-consciousness, impulse control, and stress coping. The attentional control mechanisms that underlie these various facets may differ. This was observed in the study by DeYoung and colleagues (2009) where only two facets (Ideas and Values) of the FFM trait Openness to Experience were correlated with WM capacity. Specifically, Values was positively correlated with *n*-back task accuracy and general intellect, and Ideas was positively correlated with *n*-back, OSpan, general intellect, and increased fMRI activation in left anterior prefrontal cortex and posterior medial frontal cortex during *n*-back task performance. Future work might employ the NEO-PI-R as a personality measure in order to obtain scores for these subordinate traits. In addition, the results of the present study taken together with those of DeYoung and colleagues (2009) suggest that higher-powered, large-scale (e.g., N>300) studies may be required to obtain sufficient variability in WM capacity and personality traits to detect relationships between the two.

Finally, this study included a sample of typical college-age students. Though we detected relationships between WM and Neuroticism and Openness in the sample, the most clinically meaningful contribution of these relationships is likely to be observed in extreme personality traits (cf., Duchek et al., 2007). For example, variability in Neuroticism in the general college population yielded a moderate effect on cognitive function; however, extreme levels Neuroticism (high or low) should have even greater cognitive impacts. Consistent with this argument, we observed a larger effect size for self-reported neuroticism when using extreme groups as defined by individual differences in working memory capacity/OSpan performance (albeit within a non-clinical population). Comparing cognitive impacts of extremes in personality traits may allow for better dissociation between attentional control mechanisms. This process dissociation framework (Jacoby, 1991) has been used to successfully study mental processes in a variety of cognitive domains. Such process dissociation techniques may be useful for studying the relationships between executive function (e.g., WM capacity) and personality. That is, extreme groups may be more likely to reflect an imbalance of proactive and reactive control processes, and would allow for designs that place proactive and reactive control mechanisms in opposition to each other. In combination with relatively pure measures of proactive and reactive control, this would allow for more rigorous testing of dual mechanism theories of attentional control, such as the DMC theory. However, it is important to note that while theoretically important and informative, such studies should be augmented with additional experiments that seek to determine how proactive and reactive control may work together in a coordinated fashion, rather than in isolation or in an unbalanced manner, to coordinate cognitive control (cf., Miller, Watson, & Strayer, 2010). The optimal interaction of these two cognitive control processes may be necessary to bring about the full spectrum of executive attention, both in more traditional laboratory experiments as well as in everyday contexts.

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